

# APPLICATION FOR UNITED STATES LETTERS PATENT

**0697-1160**

## **SYSTEM AND METHOD FOR MANAGING COMPRESSED GRAPHIC IMAGE DATA**

### **FIELD OF THE INVENTION**

This invention relates to graphic image display. More particularly, this invention relates to a system and method for efficiently managing compressed geographic image data, such as Compressed ARC (Arc-second Raster Chart/map) Digitized Raster Graphics (CADRG) data, and displaying images therefrom.

### **BACKGROUND**

Many applications require storage and retrieval of data from among vast amounts of graphic image data. To reduce storage requirements, the image data is frequently stored on media in a compressed format. Conventional systems typically decompress an entire file containing data for an image before loading it into memory. The data for the image is then sent to a frame buffer for display on a display device. While decompression prior to loading data in memory may facilitate display, it does so at the expense of memory and hardware cost. The decompressed data will occupy much more memory than its compressed counterpart, increasing hardware cost and/or leaving less memory available for storing other data and for other purposes.

Conventional systems typically do not maintain files of interest in memory for repeated use. If sufficient memory is available, a first decompressed file may occupy a significant portion, if not all, of the available memory in a conventional system. When data from a second file is needed, memory in which the first decompressed file is stored is deallocated and the second file is decompressed and loaded into memory. If data from

the first file is needed later, the entire process must be performed again, swapping the first file for the second file. As the system must access a disk to decompress and load the desired file into memory each time it is needed, this process is time consuming and inefficient and reduces response time.

5           Conventional systems are also typically unable to efficiently isolate data for a subsequent image from a decompressed file in memory. After displaying a first image from a decompressed file loaded in memory, many systems will reload the file from disk into memory to access data for a second image. This reloading operation entails accessing the disk and decompressing the file. Other systems will read and rewrite the entire decompressed file in memory to cull out data for the image of interest, a process which is conducive to memory fragmentation.

Such use of resources compromises the performance of a conventional graphic image display system by relying heavily on redundant disk access operations to load data into memory. Memory provides storage at a higher cost per megabyte than hard disks and CD-ROMs, but typically with relatively fast access and data transfer rates. In sharp contrast, hard disks and CD-ROMs provide relatively inexpensive non-volatile storage for large amounts of data, but take substantially more time to access and transfer data (often hundreds or thousands of times longer than the time taken to access data in memory), thereby creating a bottleneck.

20           Delays caused by accessing and transferring data from a disk can be particularly acute in the case of a conventional geographic display system, such as a system for

displaying geographic images from CADRG data. Frequently, a sequence of images is displayed, starting with a first geographic image, then one or more other images for contiguous regions. Even if a single file contains the data for these images, many conventional systems must decompress the file and reload the data into memory to access  
5 the data for successive images. Common operations, such as flipping back and forth between two images, panning and cycling through a series of images, may entail multiple disk access, loading and decompression operations, consuming substantial time.

Instead of decompressing data for only an area of interest, conventional systems typically decompress an entire file, further compromising performance. Such indiscriminate decompression wastes both time and memory.

Frequent memory allocation and deallocation operations performed by conventional systems may further compromise performance. Such operations are conducive to memory fragmentation, especially in systems running multithreaded applications and multitasking operating systems, and consume valuable time. Memory can be viewed as a continuous range of allocatable cells. Fragmentation, the occurrence of unused gaps between useful cells in memory, can both increase the requirement for memory and slow down computation due to less efficient use of the storage hierarchy and complexity of memory access.

## SUMMARY

It is therefore an object of the present invention to provide a system and method for

efficiently managing compressed geographic image data, such as CADRG data.

It is another object of the invention to provide a system and method for storing compressed geographic image data, such as CADRG data, in memory and decompressing requested data for only an area of interest within a file before sending it to the frame buffer for display.

It is also another object of the invention to provide a system and method for maintaining compressed geographic image data, such as CADRG data, stored in memory for decompression and display as requested.

It is yet another object of the invention to provide a system and method that displays images from compressed geographic image data and reduces the likelihood of memory fragmentation.

It is a further object of the invention to provide a system and method that displays images from compressed geographic image data and stores requested graphic image data files in blocks of memory as nodes of a linked list.

It is also a further object of the invention to provide a system and method that displays images from compressed geographic image data, stores requested graphic image data files in blocks of memory as nodes of a linked list, with each node including a flag field for indicating whether or not the node is in use, and maintains unused nodes in the linked list and data in such nodes available for use and replacement.

To accomplish these and other objects of the present invention, a system and method are provided for storing compressed graphic image data, such as CADRG files,

in blocks of memory (nodes) arranged as a linked list. Files are loaded in memory in compressed format, consuming substantially less memory than their decompressed counterparts. Only the portions of files that contain requested data are decompressed before the requested data are sent to the frame buffer for display. Once loaded in memory, a compressed file is maintained in memory for further use, until the memory is otherwise needed by another file containing data for a new region of interest. Nodes that do not contain requested data are flagged as unused, but not deallocated, making the data in such nodes available for use or replacement.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

The foregoing and other objects, features and advantages of the present invention will become better understood with reference to the following description, appended claims, and accompanying drawings, where:

Figure 1 is a block diagram of an exemplary graphic image display system for implementing the present invention;

Figure 2 shows conceptually a typical CADRG frame (or tile) comprised of 36 subframes, each having 65,536 pixels;

Figure 3 depicts a block of memory (or node) comprised of a flag field, a data field and a next field in accordance with a preferred implementation of the present invention;

Figure 4 is a schematic of a linked list comprised of nodes and a head pointer in accordance with a preferred implementation of the present invention;

Figure 5 is a schematic of a linked list that illustrates the process of appending a

node in accordance with a preferred implementation of the present invention;

Figure 6 is a schematic of a linked list that illustrates the process of pushing a node in accordance with a preferred implementation of the present invention;

Figure 7 is a schematic of a linked list that illustrates the process of inserting a node in accordance with a preferred implementation of the present invention;

Figure 8 is a schematic of a linked list that illustrates the process of replacing data in an unused node in accordance with a preferred implementation of the present invention;

Figure 9 is a schematic of a linked list that illustrates the process of flagging nodes as used or unused over a period of time, t1 to t3, in accordance with a preferred implementation of the present invention;

Figure 10 is a perspective of a globe with latitudinal bands dividing the globe into 18 zones, with the northern and southern hemispheres each having 9 zones; and

Figure 11 is a flowchart of an exemplary process for managing compressed image data and displaying images therefrom in accordance with the present invention.

## DETAILED DESCRIPTION

The present invention provides a system and method for efficiently managing compressed graphic image data and displaying graphic images therefrom. The method involves storing compressed graphic image data, such as CADRG files, in blocks of memory (nodes) arranged as a linked list. Only the portions of files containing requested data are decompressed before the requested data are sent to the frame buffer for display. Nodes that do not contain requested data are marked as unused, but not deallocated,

making the data in such nodes available for use or replacement.

Referring to Figure 1, an exemplary system for displaying graphic images in accordance with the present invention preferably includes a bus **150** for communicating information, a central processing unit (CPU) **110**, a read only memory (ROM) **120**, random access memory (RAM) **130**, a frame buffer **140**, a storage device **160**, a display device **170** and an input device **180**. The storage device may include a hard disk, CD-ROM drive, tape drive, memory and/or other mass storage equipment. These elements are typically included in most computer systems and the aforementioned system is intended to represent a broad category of systems supporting image display devices. Of course, the system may include fewer, different and/or additional elements, provided it is capable of selectively processing compressed graphic image data and displaying images therefrom. Additionally, the system may either stand alone or operate in a distributed environment.

An image on the display device **170** is made up of individual dots known as pixels (short for picture elements). The frame buffer **140**, which can be a designated part of main memory or a separate memory designed for image display, stores data representative of each pixel. The display **170** is usually serially addressed, with pixels being sent to the display one at a time, starting at the top left corner of the screen and scanning along each line sequentially until the bottom right corner is reached. For analog display devices, frame buffer data is typically translated from binary to one or more voltages for each pixel. To allow new image data to be generated while a current image is being scanned to the display, many conventional architectures include two frame buffers.



An important aspect of a preferred implementation of the present invention is that files containing desired image data are stored in memory in compressed format, rather than decompressed format as in conventional systems. Thus, the present invention efficiently uses available memory, with each stored file consuming substantially less memory than its decompressed counterpart. Conserved memory may be used for storing other data or for other purposes. This aspect of the present invention also facilitates implementation on systems with relatively little memory.

Another important aspect of a preferred implementation of the present invention is that only the portion of a file that includes data for an area of interest is decompressed. Decompression of data for an area of interest can typically be performed more quickly than decompression of an entire tile, and much more quickly than loading a file containing the data from a disk.

In a preferred implementation of the present invention the data may include CADRG map and chart data. CADRG is intended for use in a variety of military and civilian applications requiring map backgrounds, coordinate selection and perspective view generation. Military applications include mission planning systems, theater battle management systems and intelligence systems. Civilian applications include geological, environmental and navigational systems.

CADRG data are typically derived from digitized maps and charts. Original source graphics (maps and charts) for ADRG data, from which CADRG data are typically derived, are scanned at approximately a 100 micron ( $\mu$ ) pixel resolution (254 pixels per inch) in both

East-West and North-South directions, and then warped from the datum of the original paper map or chart to an ARC system of 18 latitudinal bands, transforming row and column coordinates for each pixel into latitude and longitude coordinates. Warping involves registering the raw maps and charts to known (control) coordinates. The registration record is then used to geometrically rectify the map or chart. The latitudinal bands encircle the earth's surface and divide it into 18 zones, with the northern and southern hemispheres each having 9 zones, as generally depicted in Figure 10. To produce CADRG data, ADRG source data is spatially reduced to a  $150\mu$  pixel resolution (169 pixels per inch).

CADRG data are typically arranged as rectangular grids of frames of pixels, with a discrete file representing each CADRG frame, also known as a tile. Each frame or tile typically includes a rectangular array of 1536 by 1536 pixels (2,359,296 pixels) translated into a grid of 6 by 6 subframes (36 subframes), as shown in Figure 2. Each subframe includes a rectangular array of 256 by 256 output pixel values (65,536 pixel values).

In addition to containing data representing each pixel, CADRG files contain overhead data. The overhead data include a coverage section that defines the geographical extent of the tile using sets of latitude and longitude vertices. Thus, the approximate latitude and longitude represented by any pixel in the 1536 x 1536 array comprising the tile can be determined for purposes of defining an area of interest.

CADRG data are compressed. Available colors in ADRG source data are typically quantized from a palette of 16.7 million colors to 216 colors, reserving 40 colors in an 8-bit system for other uses by application software. The 216 quantized colors (0 through 215)

are defined in a color lookup table. A 217<sup>th</sup> entry with null values may be reserved for transparent pixels. Each entry of the lookup table includes 4 bytes, one byte each for red, green and blue (RGB) intensity levels and a fourth byte for a monochrome (grayscale) intensity level.

5           The data are also spatially compressed into subframe arrays of 64 x 64 12-bit codes using vector quantization employing a 4 x 4 compression kernel size with 4096 codebook entries, each having 16 bytes. A compressed CADRG file may achieve substantial reductions in size, on the order of approximately 8:1.

Decompression, the inverse of the compression process, involves replacing the 12-bit codes with values from the tables to produce pixel values for use in display. A CADRG file includes all of the tables and codes required for decompression. Each 12-bit code in the 64 x 64 array is converted to a 4 x 4 block of 8-bit values, each ranging from 0 to 216. For a particular 12-bit code, there is an entry (or record) in each of four compression lookup tables. Each record addresses a row of the 4 x 4 block, providing four 8-bit values. The resulting 8-bit values from the four compression tables are combined to form the 4 x 4 block. Each 8-bit value in the 4 x 4 block is an index in the color lookup table that provides an RGB or monochromatic (grayscale) value.

After each 12-bit code has been converted to a 4 x 4 block of 8-bit values(indices), the indices are replaced with RGB or monochromatic (grayscale) pixel values from the color look-up table. Each pixel of a final RGB output image, therefore has a 24-bit argument.

As used herein, a region of interest means a geographic region that includes an area of interest. An area of interest means a geographic area that includes a geographic image for display. The area of interest preferably includes areas contiguous to the area covered by the geographic image for display. The geographic region preferably includes areas contiguous to the area of interest. To illustrate, a geographic region may include substantial portions of Indiana, Ohio and Kentucky. An area of interest within that geographic region may include Dayton, Ohio and surrounding areas. A geographic image for display within the area of interest may include Wright-Patterson Air Force Base.

In a preferred implementation of the present invention, only the portion of a CADRГ tile that includes data for an area of interest is decompressed. This decompression process is referred to herein as "partial decompression." The area of interest includes the area to be displayed and, preferably, some surrounding areas to facilitate panning. While the area of interest may comprise an entire CADRГ tile (1536 x 1536 pixels), preferably it comprises only a portion of a CADRГ tile. For example, the area of interest may include 1024 x 768 pixels (one third of a CADRГ tile), which exceeds the pixel display capability of many display devices. Additionally, several CADRГ tiles may collectively include the data for the area of interest, requiring data from multiple files. An important advantage of partial decompression is that it can typically be performed more quickly than decompression of an entire tile, and much more quickly than loading a file containing the data from a disk. Another important advantage is that the decompressed data for the area of interest typically consumes less memory than the decompressed data for the entire tile.

Partial decompression involves identifying the 12-bit codes for the area of interest and performing the decompression process, as described above, for those codes. Codes corresponding to the area of interest may be determined from the reference latitude and longitude vertices contained in the CADRG file, or by relation to specific reference codes (e.g., codes defining an edge of a previous image). Each 12-bit code corresponds to a 4 x 4 array of pixel values for the CADRG tile, thus representing specific geographic points within the covered geographic area. For example, a CADRG tile may cover an area defined by  $-85.75^{\circ}$  to  $-83.25^{\circ}$  longitude and  $38.88^{\circ}$  to  $40.12^{\circ}$  latitude, which encompasses portions of Indiana, Ohio and Kentucky, including the cities of Cincinnati and Dayton, Ohio. An area of interest within the tile may be defined by 12-bit codes in the 37<sup>th</sup> through 53<sup>rd</sup> (from left to right) columns of the 16<sup>th</sup> through 24<sup>th</sup> rows (from top to bottom) of the 64 x 64 array. This area of interest extends from approximately  $-84.34^{\circ}$  to  $-83.72^{\circ}$  longitude and  $39.65^{\circ}$  to  $39.96^{\circ}$  latitude, which includes Dayton, Ohio, Wright-Patterson Air Force Base and Springfield, Ohio.

Another important aspect of the present invention is that it provides means for efficiently managing compressed files in memory. A file that includes data requested for display, once loaded in memory, is maintained in memory until the data in that file is no longer required for display and the memory is requested for a new file that includes data for a new area of interest. By maintaining the file in memory, the data in that file remains available for display without having to access and load the file from a hard disk. Thus, the present invention reduces time consuming disk operations. Furthermore, maintaining the

data in memory reduces the number of memory reallocation operations, making memory fragmentation less likely.

In an exemplary implementation, requested CADRG files are stored in blocks of memory as nodes (**415**, **430** and **445**) of a linked list in a heap **460**, as depicted in Figure

4. Each node continues to exist until it is explicitly deallocated.

A node, as conceptually shown in Figure 3, preferably includes three fields— a flag field **310**, a data field **320** and a next field **330**. The flag field **310** includes a used/unused flag for indicating whether or not the node is in use. The data field **320** stores the compressed CADRG file, preferably as an object. The next field **330** includes a pointer linking the node to the next node in the list.

Referring again to Figure 4, the beginning of the linked list is stored in a “head pointer” **400** (e.g., as a local pointer in the stack), which points to the first node. The first node **415** contains a flag field marked as used **410** and a pointer **420** to the second node **430**. The second node **430** contains a flag field marked as used **425** and a pointer **435** to the last node **445**, ... and so on. The last node **445** has a null pointer **450** marking the end of the list. Any node in the list can be accessed by starting at the head and following the next pointers.

Referring now to Figure 11, a flowchart for an exemplary process implementing the present invention is shown. In step **1115**, an application makes a function call requesting certain files that include data for a region of interest. The region of interest preferably includes the area of interest and contiguous areas to facilitate panning. The size of the

area may be a function of the memory available for storing such files. The request may include a reference point (e.g., a center point or corner) and a size (e.g., a radius or a width and height) for defining a geographic area of interest in relation to the reference point. The request may be user driven, as where a user specifies a region to view, or application driven, as in a navigation or positioning system that displays an area determined by computation.

Next it is determined whether a linked list exists, as in step **1120**. If a linked list does not exist, as might be the case upon starting an application, the files containing the data for the region of interest are requested, as in steps **1120** and **1125**. The files are then stored in memory as a linked list, as in step **1130**, and ready for flagging, decompression, processing and display.

Should step **1120** determine that a linked list exists, it is then determined whether the list includes the files containing the desired data, as in step **1135**. If the list includes the files, they are ready for flagging, decompression, processing and display. If the list does not include the files, the files must be requested, as in step **1140**, and included in the list.

The method of inclusion depends upon whether or not the list includes unused nodes (step **1145**). If the list does not include unused nodes, the requested files are included in new nodes added to the list, as in step **1150**, preferably by appending to the tail end, though they may be pushed to the head end or inserted somewhere between the head and tail ends of the linked list, as shown in Figures 5 through 7. Appending, as

conceptually shown in Figure 5, involves locating the last node **530** in the list and changing the null pointer **540** to a pointer **550** to the new node **560**, which in turn will have a null pointer **570** to mark the end of the list. Pushing, as conceptually shown in Figure 6, involves changing the head pointer from the first node **670** to the new node **660**, which in turn will have a pointer **620** to the next node **630** (previously the first node). Insertion, as conceptually depicted in Figure 7, involves changing the pointer **740** of the node **720** before the inserted position to a pointer **730** to the new node **750**, which in turn will have a pointer **755** to the node **760** after the inserted position. Upon such appending, pushing or insertion, the files containing the requested data are stored in memory in the linked list and ready for flagging, decompression, processing and display.

Referring again to Figure 11 and step **1145**, if the list includes unused nodes, files requested in step **1140** will replace files in the unused nodes, as in steps **1145** and **1155**. To illustrate the replacement process, Figure 8 shows a linked list with four nodes. The first two nodes **810** and **820** and the fourth node **840** are flagged as used. The third node **830** is flagged as unused. If a function call is made requesting file CADR(5), that file will replace CADR(3) in the third node. Because CADR files of interest for most (non-polar) applications are approximately the same size, such replacements typically do not create gaps in memory or require substantial restructuring of the linked list. When performed using standard I/O (input/output) operations, the replacement step does not require memory allocation and deallocation. Upon such replacement, the tiles containing the requested data are stored in memory in the linked list and ready for flagging,



decompression, processing and display.

Referring back to Figure 11, after files containing data for the region of interest are stored in memory in the linked list, nodes are flagged, as in step **1160**. Nodes that include files which contain data for the region of interest are flagged as used. Nodes that include files which do not contain data for the region of interest are flagged as unused.

To illustrate the flagging process, Figure 9 conceptually depicts a linked list at three distinct times, t1, t2 and t3. At time t1, the third node **915** is flagged as used **910** and the fourth node **925** is flagged as unused **920**. Though the fourth node is unused at time t1, it is not deallocated and its file (CADRG(4)) remains available for use. At time t2, the file in the fourth node **945** is required and available for use without reallocation. Thus, the fourth node **945** is then flagged as used **940**. Also at time t2, the file in the third node **935** is no longer required and, thus, flagged as unused **930**. At time t3, the third and fourth nodes **955** and **965** return to the same used/unused states **950** and **960** as at time t1. By maintaining the unused nodes in the linked list, several deallocation, reallocation, disk access and loading operations are avoided.

After flagging, data for the area of interest are decompressed, as in step **1165**, and the decompressed data are stored in available memory. Preferably, only the portion of the file that includes data for the area of interest is decompressed, as discussed above for partial decompression of a tile. Upon decompression, the data for the geographic image for display are processed (i.e., culled from the data for the area of interest) **1170**, sent to the frame buffer **1175** and an image is displayed based on the data **1180**. The

decompressed data stored in available memory, whether in main memory or the frame buffer, may be retained in memory for further use until that memory is otherwise needed.

After the image has been displayed, the application may make another function call requesting different data for another area of interest, as in step **1185**. Again, the request may include a reference point (e.g., a center point or corner) and a size (e.g., a radius or a width and height) for defining a geographic area of interest in relation to the reference point. The request may be user driven, as where a user specifies a region to view, or application driven, as in a navigation or positioning system that displays a computed area. In step **1190**, if the data for the area of interest are already stored in decompressed form in memory for use, control is returned to step **1170** and the process continues. However, if the data for the area of interest is not already stored in decompressed form in memory for use, control is returned to step **1135** and the process continues.

While the foregoing description discloses use of CADRG data in a preferred implementation, other compressed graphic image data, whether geographic or non-geographic, may instead be used, and comes within the scope of the present invention. Preferably, such other data are contained in a file that can be partially decompressed, and typically in less time than it would take to either fully decompress the file or load the decompressed data into memory from a hard disk, CD-ROM, or other mass storage device. The compressed files of interest for such other data preferably include all data needed for decompression. Additionally, the compressed files of interest for such other data preferably have approximately the same size, to facilitate replacing data in unused

nodes.

The foregoing detailed description of a particular preferred implementation of the invention, which should be read in conjunction with the accompanying drawings, is not intended to limit the enumerated claims, but to disclose particular examples of the invention. Those skilled in the art should appreciate that they can readily use the concepts and specific implementations disclosed as bases for modifying or designing other methods and systems for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent methods and systems do not depart from the spirit and scope of the invention as claimed.